DEVELOPMENT OF THE CONTENT OF THE "BIOLOGY I" SET OF METHODOLOGICAL MATERIALS FOR A COMPETENCE-BASED APPROACH TO SECONDARY SCHOOL BIOLOGY

Rita Birzina, Daiga Kalnina, Sandra Kalnina
University of Latvia, Latvia
E-mail: rita.birzina@lu.lv, daiga.kalnina@lu.lv, sandra.kalnina@lu.lv

Abstract

The competence-based approach has raised important questions in education regarding the content of learning, the way teachers teach and students learn, and the assessment of learning. General education in Latvia has been reformed, and the content of competence-based education was introduced in 2023. In STEM curricula, the content is developed in the context of the Big Ideas, and the number of teaching hours is restructured. Only 105 teaching hours are foreseen for biology at the optimal secondary level, which is twice less than before. So, it was important to learn how this approach is implemented in the biology content to achieve learning outcomes defined in the Latvian secondary education standard, what opinion of biology teachers is on the content of Biology I curriculum developed by Skola2030, and what the content of the biology methodological material should be. Through mapping of learning outcomes and the survey of biology teachers, the main problems were identified: insufficient number of lessons, illogical sequence of topics and subtopics, and lack of teaching resources. On this basis, a set of Biology I methodological materials was developed.
Keywords: *biology education, content of secondary school curriculum, integration of Big Ideas, set of methodological materials, competence-based approach*

Introduction

The competence-based approach (hereafter in the text – CBA) to education changes traditional learning paradigms by emphasising the development of knowledge, skills and attitudes to deal with real-life situations (Biesta, 2009). It aims not only at providing theoretical knowledge, but also at developing practical skills and attitudes needed in today's society. The curriculum should focus on developing students' skills and abilities, not just on imparting knowledge. The curriculum content is an essential component of education as it determines what knowledge and skills students will acquire, as without a conceptual base students cannot innovate (Wiggins & McTighe, 2005), and the standardisation of content ensures equity between educational institutions by allowing for objective assessment of competency performance (Hattie, 2009; OECD, 2018). Structured content guides educators by reducing the need to create materials themselves, which is particularly important for new teachers (Darling-Hammond et al.,

This is an open access article under the **Creative Commons Attribution 4.0 International License**
https://doi.org/10.33225/BalticSTE/2025.30

2020). However, ambiguity in the curriculum can hinder teachers' work (Amadio et al., 2014), and a too rigid focus on content can lead to the mechanical reproduction of knowledge rather than its application.

Biesta (2009), describing the three functions of education as qualification, socialisation, and subjectification, warns that the CBA can degrade education into functional skills training if the content is seen as an end in itself. The overload of new content elements without getting rid of old ones can increase the time spent learning topics, leaving less time for the practical application of competences (Voogt & Roblin, 2012; Priestley & Sinnema, 2014).

Curriculum content is essential for implementing a CBA in STEM subjects, providing theoretical foundations, practical skills, and interdisciplinary thinking (Bybee, 2013). In biology, it builds an understanding of life processes and their interrelationships. Teachers face both advantages and challenges in implementing the competence-based approach.

The main advantage of the CBA is the focus on students' ability to apply knowledge in real-life situations. In biology, this means applying theoretical knowledge, for example, in experiments or in the analysis of ecological problems. It also promotes the integration of subjects, such as working together with chemistry, physics, and mathematics to develop a holistic understanding of science (Krauss, 2024). Furthermore, it allows for the tailoring of the curriculum and methods to the needs of each student, promoting individual growth (Tomlinson, 2014).

The main challenge of the CBA is the increased investment of teachers' time and resources (Hattie, 2009). In biology, this means additional laboratory equipment and experiment time. It requires teachers to acquire new skills and professional development (Darling-Hammond, 2010), especially the acquisition of new pedagogical methods and the integration of curriculum with other STEM disciplines. Competency assessment can be more complex compared with the traditional methods, as not only knowledge but also skills and attitudes need to be assessed (Black & Wiliam, 1998).

In Latvia, the introduction of the CBA started in 2016 with the European Social Fund project "Competence-Based Approach in the Curriculum" implemented by the National Centre for Education Content. The aim of the project was to develop and implement a curriculum that promotes students' ability to apply knowledge in practice by developing critical thinking, problem-solving skills, and creativity. Existing curricula were reviewed to reduce fragmentation and to enhance students' ability to apply knowledge to real-life situations. Seven areas of learning were identified: language; social and civic; cultural awareness and self-expression in the arts; science; mathematics; technology; health, safety, and physical activity. For each of these areas, learning outcomes and model curricula were developed that integrate the eight transversal competences: self-directed learning, critical thinking and problem solving, creativity and entrepreneurship, collaboration and civic engagement, and digital literacy (Skola2030, 2019). There are three levels of learning in any subject area in secondary education: the general level of learning, the optimal level of learning, and the highest level of learning.

The number of teaching hours was also changed for science subjects. The previous, still valid, standard for general secondary education provided for the same number of hours (210) for the subjects of biology, chemistry and physics, but the new concept provides for twice as few hours for the subject of biology (105 hours; compared to 245

https://doi.org/10.33225/BalticSTE/2025.30

for physics and 210 for chemistry) (Ministru kabinets, 2019). The school can implement this curriculum in one academic year with 2 lessons per week and in 1.5 academic years with one lesson per week.

The content of the STEM subject curriculum was developed based on the Big Ideas (Harlen, 2015), including 10 big questions taught separately in biology, physics, chemistry, and geography, and big questions to be taught together (Table 1). Big questions 7-10 are covered in biology as a separate subject.

Table 1

Integrating Big Ideas Themes into Science Subjects

Big Questions acquired in separate subjects	Big Questions taught together
1. All matter in the Universe is made of very small particles 2. Objects can affect other objects at a distance 3. Changing the movement of an object requires a net force to be acting on it. 4. The total amount of energy in the Universe is always the same, but it can be transferred from one energy store to another during an event 5. The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth's surface and its climate 6. Our solar system is a very small part of one of billions of galaxies in the Universe 7. Organisms are organised on a cellular basis and have a finite life span 8. Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms 9. Genetic information is passed down from one generation of organisms to another 10. The diversity of organisms, living and extinct, is the result of evolution	11. Science is about finding the cause or causes of phenomena in the natural world 12. Scientific explanations, theories, and models are those that best fit the evidence available at a particular time 13. Applications of science often have ethical, social, economic, and political implications

The SCAP assessment system is used in education in Latvia. This system helps teachers to assess students' learning outcomes and give feedback on their progress. The SCAP assessment system consists of four levels (Table 2).

- Starting to acquire (S): Indicates that the learner has begun to learn the content but has not yet achieved sufficient understanding or skills.
- Continuing to acquire (C): Indicates that the learner is continuing to learn the content and has made progress, but has not yet fully acquired the required knowledge and skills.
- Acquired (A): Indicates that the learner has mastered the content and demonstrates sufficient understanding and skills.
- Proficient (P): Indicates that the learner has mastered the content in depth and demonstrates a high level of understanding and skills.

https://doi.org/10.33225/BalticSTE/2025.30

Table 2
SCAP Assessment System

	Starting	to acquire	Continuing to acquire	Acquired	Acquired proficiently
Points	1–2	3–4	5–6	7–8	9–10
Percentage	0–20 %	21–40 %	41–66 %	67–86 %	87–100 %

Research Problem

In today's education system, the CBA has become a priority to prepare students not only for acquiring knowledge, but also for applying it skillfully in real-life situations. Biology, as a branch of science, provides many opportunities to develop critical thinking, problem-solving skills, and collaboration, which are essential aspects of the competence approach. Despite educational reforms and the introduction of new teaching approaches (OECD, 2018), teachers and students still face difficulties in applying the CBA effectively to learning biology. This leads to a situation where students do not always develop higher-level thinking skills and are unable to apply knowledge to real-life situations. OECD PISA data show that Latvian students' performance in science is average or below average compared to other countries (OECD, 2019), indicating a need to improve analytical and problem-solving skills. Developing the curriculum content in a CBA can be a challenge, as existing content and teaching methods often do not meet modern educational requirements and students' individual needs (Skola2030, 2019), so it is important to review the Skola2030 biology content and involve the content implementers - biology teachers - in its evaluation.

Research Focus

In Latvia, the content of competence-based education was fully implemented in general education in 2023. The curriculum reform has marked a shift in teaching and pedagogical approaches (OECD, 2020). In 2023, a set of methodological materials was developed within the framework of the European Social Fund-funded project "Support for the Development of Individual Competences of Learners" (No 8.3.2.2/16/I/001) sub-project "Digital Authoring Solutions for the Development of Learning Strategies for STEM Content Learning to Mitigate the Impact of Pandemic (Biology I)" (Identification No VISC 2023/2). In collaboration with the academic staff from the Faculty of Biology (now Faculty of Medicine and Life Sciences) of the University of Latvia and practising teachers, a restructured alternative Biology I curriculum was developed, covering seven topics relevant to the Education Standard of Latvia and the Big Ideas, and 105 lessons were developed. All developed teaching materials were uploaded to the authorised website Skolo.lv, and biology teachers have access to it. According to the current portal data (25.02.2025), the resource has 456 users.

https://doi.org/10.33225/BalticSTE/2025.30

Research Aim and Research Questions

In order to create a set of methodological materials that would meet the needs of teachers, it was necessary to study the content and relevance of the Biology I curriculum developed by Skola2030, as well as to find out teachers' opinions on the implementation of the curriculum in school. The aim of the study was to investigate how the CBA is implemented in the Biology content. To do this, a number of research questions were set:

1. To what extent does the Biology I curriculum developed at Skola 2030 meet the outcomes set out in the Latvian Secondary Education Standard?
2. What are the opinions of biology teachers on the content of the Biology I curriculum developed by Skola2030 in the context of the competence-based approach?
3. How and what was the content of the Biology I methodological materials developed in order to achieve the learning outcomes set in the Education Standard of Latvia?

Research Methodology

General Background

In order to answer the question to what extent the model Biology I curriculum developed by Skola 2030 meets the outcomes set out in the Education Standard of Latvia, the mapping of learning outcomes was performed. All the outcomes included in the topics were mapped against the outcomes set in the standard. Subsequently, a content analysis was performed to determine whether the full achievement of the outcomes set out in the standard is expected, and to identify issues that do not appear in the list of curriculum outcomes.

In order to find out how the model Biology I curriculum developed by Skola2030 is implemented in schools, a survey was carried out with the participation of secondary school biology teachers in Latvia. Based on the survey of teachers' opinions, an alternative set of Biology I methodological materials for teachers was developed.

Sample

A survey of biology teachers was conducted in 2023 and 2024. 97 biology teachers from Latvian gymnasia (28%) and secondary (72%) schools participated in the survey (length of service: 1/2-10 years - 23.3%; 11-20 years - 17.1%; 21-30 years - 29.5%; 31-45 years - 21.9%). Of these, 11% were male and 89% female, with the majority (49%) aged between 51 and 65 years. The teachers surveyed represented schools in Riga City (43.2%), urban schools in the municipalities (33.8%), public schools in the cities (12.9%), and schools in rural areas (10.1%).

Instrument and Procedures

The mapping was carried out using the General Secondary Education Standard of Latvian Cabinet of Ministers Regulation No 416, Annex 5 (Cabinet Regulations...,

https://doi.org/10.33225/BalticSTE/2025.30

2019), the content for the Optimal Level of Learning and Biology I: Model Curriculum for the General Secondary Education (Biology I.., 2019)

The questionnaire was structured in two parts (Figure 1). The first part elicited information on the respondent's profile (sex, age, type of school, length of service, and subject taught). In the second part, respondents answered 10 closed-ended (Q7.1-Q7.10) Likert scale questions on a 5-point scale (1 = strongly disagree, 5 = strongly agree) and 3 open-ended questions. The closed-ended questions assessed the School 2030 Biology I curriculum in the context of the CBA, focusing on the relevance of the curriculum content to the core principles of the competence-based approach.

Figure 1

The Structure of the Questionnaire

Profile of the respondent	Content of the model programme
Gender Age School type School location Years of experience Subject	**1.** 10 closed-ended Likert scale questions (Q7.1-Q7.10) on the aim of the programme, the outcomes to be achieved, the number of lessons, the topics, their arrangement and sequence **2.** Four open-ended questions (Q8, Q9, Q10, Q11) on the content, problems in learning the topics and suggestions for solving them

The survey was hosted on the *QuestionPro* e-platform and initially used a snowball method to engage respondents. The link to the survey was then placed on the Skolo.lv website accessible to teachers next to the created set of Biology I methodological materials.

The teacher survey on the content of the model Biology I curriculum developed by Skola 2030 asked four open-ended questions: Q.8. Another answer (supplement to questions Q7.1-Q7.10). Q9. About the content of the Programme, I can say that ... (positive/negative opinion, reasons for it). Write your answer; Q10. I have difficulties in teaching certain topics (Write your answer, indicating the topic and the problem. If there are no difficulties, indicate NONE); Q11. What should be done to eliminate these problems?

Data Analysis

Mapping the learning outcomes to be achieved. All the expected student learning outcomes at the optimal level in the subject of Biology standard were mapped in an Excel file. Then, all the outcomes defined in the model topics of the Biology I programme were mapped against them, according to the reference to the corresponding outcome of the standard. A content analysis was then carried out to determine the relevance by assigning the following labels to the standard outcomes: fully covered, partially covered, and not included in the curriculum. The results, together with the conclusions on the identified gaps, were shared with the developers of the methodological materials so that the gaps could be addressed in the development of the materials.

https://doi.org/10.33225/BalticSTE/2025.30

Analysis of survey data. Descriptive statistics (Mean and Standard deviation), Cronbach's alpha were used to assess the internal consistency of the survey. It was found that the questions had high consistency ($\alpha = 0.945$). As the data were not normally distributed and the sample size was small ($N = 97$), non-parametric statistical methods were used.

In order to find out what the content of Biology I methodological materials should be in order to achieve the learning outcomes set out in the Education Standard of Latvia, teachers' answers to open-ended questions were collected, and an alternative set of Biology I methodological materials was created. The developed teaching materials were mapped to the learning outcomes to confirm their compliance with the Education Standard of Latvia.

Research Results

Mapping the Learning Outcomes to be Achieved

The mapping and content analysis showed that 24% of the deliverables indicated in the Standard are fully covered, 41% are partially covered, and 35% of the deliverables are not included in the curriculum. An example of the mapping and content analysis of one of the Standard's deliverables is shown in Table 3.

Table 3
An Example of the Mapping of One of the Learning Outcomes Set in the Standard

Learning outcome set in the standard	The learning outcome defined in topic 2, referring to the specific learning outcome of the standard	The learning outcome defined in topic 4, referring to the specific learning outcome of the standard	Conclusions and necessary improvements
9.1.2. Explains the causes of genetic diversity using a variety of information about fertilisation, the results of cell division, and their role in nature, using the terms gene, DNA, chromosome, mitosis, meiosis, zygote, haploid, diploid	Explains the importance of the processes of mitosis and meiosis in nature by studying root tip cell division under a microscope, calculating the number of chromosomes in the germ cells of different organisms, inferring the process of sex determination, the process of pregnancy, structuring and analysing information. (D.O.7.4.1.; D.O.7.4.2.; D.O.7.1.1.; D.O.9.1.2.; D.O.11.2.1.)	Constructs a family tree using common symbols to predict the diversity of individuals based on a characteristic feature. (D.O.9.1.1.; D.O.9.1.2.; D.O.11.2.3.; D.O.11.3.1.)	The programme outcomes need to be extended to ensure that the student can explain the causes of genetic malformation and that all the concepts in the standard are covered

https://doi.org/10.33225/BalticSTE/2025.30

Survey Results

Using the quantitative and qualitative data from the survey, the main teacher insights into the content and implementation of the model programme were identified.

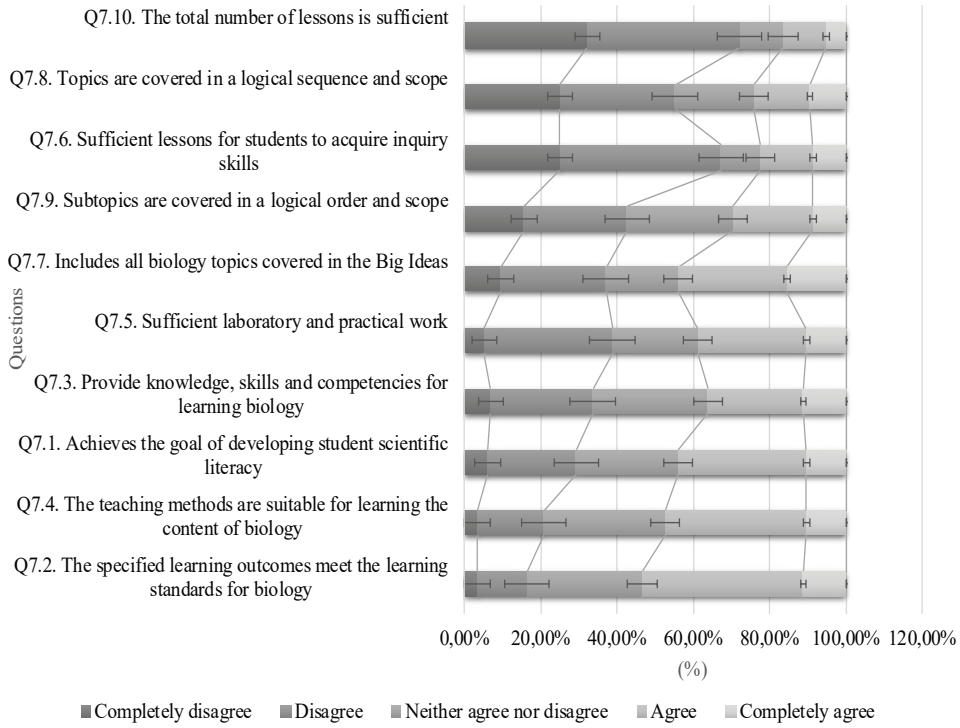
Evaluation of the Biology I programme developed by Skola2030

As shown in Figure 2, the highest mean score was given to Q7.2 on the achievement of the learning outcomes that meet the educational standard (M = 3.44, SD = 0.975), thus achieving the goal of building scientific literacy (Q7.1) (M = 3.18, SD = 1.098), as well as the appropriateness of teaching methods for learning biology (Q7.4) (M = 3.36, SD = 0.975).

The lowest ranked aspect of the curriculum content was the insufficient number of teaching hours (Q7.10) (M = 2.18, SD = 1.156), which also affects the development of students' research skills (Q7.6) (M = 2.40, SD = 1.241). The insufficient sequence and scope of sub-topics (Q7.9) (M = 2.82, SD = 1.187) was found to cause problems in the logic of content implementation (Q7.8) (M = 2.55, SD = 1.272), yet the programme covers all topics included in the Big Ideas (Q7.7) (M = 3.12, SD = 1.255).

Figure 2

Teachers' Views on the Content of the Curriculum Developed by Skola2030 and Its Implementation


Q7.10. The total number of lessons is sufficient
Q7.8. Topics are covered in a logical sequence and scope
Q7.6. Sufficient lessons for students to acquire inquiry skills
Q7.9. Subtopics are covered in a logical order and scope
Q7.7. Includes all biology topics covered in the Big Ideas
Q7.5. Sufficient laboratory and practical work
Q7.3. Provide knowledge, skills and competencies for learning biology
Q7.1. Achieves the goal of developing student scientific literacy
Q7.4. The teaching methods are suitable for learning the content of biology
Q7.2. The specified learning outcomes meet the learning standards for biology
Questions
0,00% 20,00% 40,00% 60,00% 80,00% 100,00% 120,00%
(%)
Completely disagree
Disagree
Neither agree nor disagree
Agree
Completely agree

https://doi.org/10.33225/BalticSTE/2025.30

Overall, the mean scores for these questions range from the lowest arithmetic mean (M = 2.18) for Q7.10 to 3.44 for Q7.2. The lowest scores are for the number of teaching hours, indicating the need to increase both the total and the number of practical lessons. The largest standard deviations (SD > 1.2) are for Q7.6, Q7.7 and Q7.8, showing considerable variation in responses between respondents.

The open-ended survey questions were analysed to elicit teachers' perceptions of content aspects. In general, teachers identified a variety of problems, which can be grouped into 1) insufficient number of lessons, which makes it difficult to learn the content in depth and more qualitatively; 2) difficulties in teaching specific topics such as ecology, cell reproduction, immunity and DNA secrets; 3) chaotic programme structure - topics and sub-topics are not logically arranged; 4) lack of materials and methodological support: teachers have to create their own teaching materials, as outdated or insufficient content is offered, and often in topics where teaching materials are lacking, discussions or group work is offered; 5) confusion about the depth and breadth of topics to be covered by students; and 6) insufficient preparation of students, as they have not acquired sufficient background knowledge from studying biology in primary school.

The aggregated teacher responses on the content of biology can be found in Table 4.

Table 4

Assessment of the Biology I Content

Topic	Teachers' comments (quotes from teachers' responses)
1. Environment and evolutionary change in organisms	If biology is not taught in Grade 10, it is very difficult to work in Grade 11, because students remember very little. Chaotic planning. Basic questions are not acquired, but students are forced to make deep judgements about processes in nature. According to the new approach of School 2030, students in primary school have not learnt about the diversity of plants and animals, so it is very difficult to work on this topic, because you cannot teach ecology without learning about the systematics, anatomy, morphology of plants and animals as well as other organisms. It is very difficult to plan and carry out project work: a field study with 1 hour per week! It is not realistic to carry out the interdisciplinary project "Water", because there are no relevant topics in other subjects at this time.
2. Cell reproduction	It is difficult to talk about cell reproduction and the secrets of DNA without first learning about the structure of the cell. Artificial insemination - there is a lack of material in a language that young people can understand. No information on new research, developmental trends, real use.
3. The secrets of DNA	The chemical composition of the cell is not included. I additionally teach the chemical composition of the cell before the secrets of DNA. The information on the latest biotechnological developments is 10 years old.

https://doi.org/10.33225/BalticSTE/2025.30

Topic	Teachers' comments (quotes from teachers' responses)
4. The inheritance of traits	There is no difficulty in presenting the topics, but the order is not clear, so I change places. Students who have not chosen to study biology in depth lack motivation to learn, so it is difficult to understand how much depth is needed, and there are not enough lessons to cover the topic sufficiently.
5. Immunity of the organism	No information on newer research - immunity, allergies, GMOs, cloning, transplantation, etc. It takes a very, very long time to find quality information, compile it and create a lesson. Lack of materials, lots of extra work, having to find the information yourself (immunity, endocrine system). Wherever there is a lack of information - the programme suggests using discussion, mind maps or group work, but I need to be able to supplement and explain with real, relatively recent examples (not 10 years old) from medicine or agriculture.
6. Cells and organism functioning	The sequence of topics is not clear at all - why is cell structure at the end of the programme, how can one learn about cell division and genetics without knowing it? Too few lessons. More lessons are needed for the whole programme. Illogical continuation of the subject of immunity. Some of the outcomes and content are duplicated in Biology II. Very little coverage of the functioning of the body. It is intended to be taught extensively and in a complex way in primary school, but it is difficult for students of this age to understand many of the issues. There is a lack of order in the sequence of topics, e.g., students learn protein synthesis and only then the components of the cell.

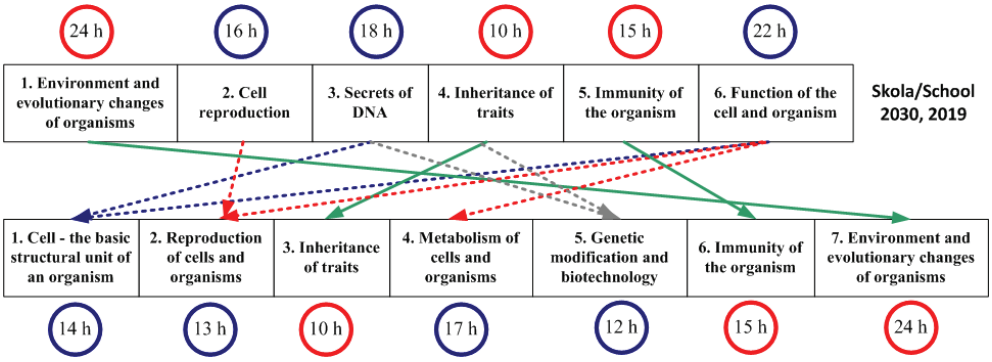
Development of the Set of Methodological Materials Biology I

Based on the teacher survey and the recommendations of the project team, an alternative Biology I curriculum was developed. The curriculum included other topics and sub-topics, a different sequence of topics, and a different number of lessons (Figure 3). The first topic *Cell - the basic structural unit of an organism* combined information from topics 3 and 6 (Skola 2030), the second topic *Reproduction of cells and organisms* included information from topics 2 and 6 (Skola 2030), topic 4 *Metabolism of cells and organisms* - topic 6 (Skola 2030), topic 5 *Genetic modification and biotechnology* - fragments from topics 3 and 4 (Skola 2030). Themes 3, 6, and 7 remained unchanged in terms of the number of lessons, but not in terms of content.

https://doi.org/10.33225/BalticSTE/2025.30

Figure 3

School 2030 Comparison of Biology I Model Curriculum and Biology I Methodological Materials



For each topic, the appropriate number of lessons was developed, following the same lesson structure: the title of the lesson, its place in the topic and subtopics, the lesson outcome (standard and lesson outcome), evidence of the achievement of the outcome, the transversal competences, a list of resources needed for the lesson, a lesson description with activities for both the student and the teacher to do during the lesson with a suggested time plan for each activity, possible additional resources that could be used in the lesson. The lesson was supplemented with a methodological commentary on the lesson, explaining why the lesson was designed in the way it was, the possibilities to modify and adapt the lesson to the teacher's own needs, and other valuable notes.

Supplementary materials were added to most of the lessons:

- student worksheets in editable and printable formats with solutions and methodological comments;
- lab reports in editable and printable format with methodological comments;
- final assignments in two versions in editable and printable formats with solutions and evaluation criteria, as well as methodological comments;
- other materials (videos, presentations, games).

The mapping of the learning outcomes was carried out during the development of the materials, thus ensuring that all outcomes are included in the resource. Four teacher workshops were held during the development of the materials, during which the lessons developed were evaluated. After the evaluation, 29 lessons were piloted in eight schools.

All the materials (Bioloģija I.., 2023) developed for teachers are available on skolo.lv, the authorized free virtual learning platform for teachers and students.

Discussion

The European Social Fund project "Competence-based approach in the curriculum" (Skola2030, 2019) aimed at developing and implementing a modern, competence-based curriculum from pre-school to secondary school. The development of the Biology I curriculum for the optimal level of secondary school posed significant challenges, as the reduced 105 teaching hours had to include extensive Big Ideas-based content: out of 10 different big questions, four questions were dedicated only to the subject of biology,

https://doi.org/10.33225/BalticSTE/2025.30

while the remaining 6 were dedicated to physics, chemistry and geography. As the teacher survey (Figure 2, Table 4) showed, the main difficulties were: 1) the insufficient number of lessons, which makes it difficult to cover the content in a deeper and more qualitative way; 2) the teaching of certain topics, such as ecology, cell reproduction, immunity and the secrets of DNA; 3) illogical sequencing of topics and sub-topics; 4) lack of materials and methodological support; 5) confusion about the depth and breadth of topics to be covered by students; 6) insufficient preparation of students.

Insufficient number of lessons makes it difficult to learn content in depth and more qualitatively. Research shows that more lessons are directly related to better student achievement (Mullis, et al., 2020), as teaching requires sufficient time for students to understand complex processes and concepts (Anderson & Krathwohl, 2001). Harlen and Qualter (2004) highlight that lack of time in STEM subjects leads to superficial content learning, resulting in students not developing critical thinking and problem-solving skills, which reduces the likelihood of building lasting knowledge (Darling-Hammond et al., 2020). Lack of time in biology lessons prevents teachers from engaging students in laboratory work, experiments, or discussions.

Difficulties in learning specific topics often require abstract thinking. Smith et al (1994) found that students associate ecological concepts only with theory rather than real-world application. This suggests the need to strengthen the link between theory and practice. Students also often have misconceptions about biological processes, which require additional time to clarify (Dauer & Long, 2015). Topics on cell reproduction, immunity, and the mysteries of DNA also require specific approaches and resources for students. As Tibell and Rundgren (2010) point out, difficulties have been reported in molecular biology regarding various aspects of genetics, cell structure and function, macromolecular structure, cell metabolism, and biophysical concepts.

Thus, there is a need for more structured explanations and multimedia integration in the learning of biology, which in turn requires learning materials and methodological support. The lack of materials and methodological support is a significant problem, as it increases teachers' workload if they lack accessible resources (OECD, 2019). This problem is also relevant in the Latvian education system (Birzina et al., 2023). In fact, the lack of teaching materials should be seen in a much broader context, starting from printed teaching materials, then digital ones, and finally reaching laboratory equipment (Sayan & Mertoglu, 2020). Materials developed by teachers themselves may often not meet the educational standard, and inadequate teaching materials may not always ensure systematic learning of the content.

A chaotic curriculum structure creates difficulties for both teachers and students if it lacks coherence and depth (OECD, 2019). In biology, the main difficulty is to relate different concepts at the cellular level and at the organism level (Verhoeff, et al., 2008). If topics (cell division) are taught before basic concepts (cell structure) in the biology curriculum, this leads to knowledge fragmentation. The competence-based approach requires a modular structure in which concepts are developed gradually. Uncertainty about the depth and breadth of topics affects the learning process. Education reform research (Hattie, 2009) shows that clearly defined goals and expectations are important for students' success. Lack of guidelines on the level of detail to be covered in specific topics creates problems in the curriculum implementation, so clearly defined objectives and benchmarks are essential to ensure that all students have the opportunity to acquire

https://doi.org/10.33225/BalticSTE/2025.30

the necessary competences. Vagueness contributes to superficial learning of content (Meyer et al., 2014).

Students' lack of preparation makes it difficult for them to learn biology at secondary school. Without a solid background, the content of the secondary school biology curriculum can become very challenging for students, as evidenced by the research of Eija et al. (2017) on the importance of systematics knowledge in primary education. Good background knowledge motivates students to learn biology (García-Pérez, & Peñaloza, 2025) and promotes understanding of biology when learning is linked to a context-based and science-technology-society approach (Bennett, 2007). Research on student success in higher education (Birzina et al., 2019; Binder et al., 1019) shows that students with lower prior knowledge at school, compared to students with higher prior knowledge at school, are unable to bridge the knowledge gap in the first year of university without further support.

Conclusions

The mapping of the learning outcomes made it possible to assess the extent to which the model Biology I curriculum developed by Skola 2030 meets the outcomes set out in the Education Standard of Latvia. The content analysis of the mapping of learning outcomes determined whether all the learning outcomes set out in the standard are included in the learning outcomes of the topics and how fully they are reflected. Potential gaps or missing aspects were identified, thus helping to ensure that the content is aligned with the standard and to develop the curriculum and methodological materials in line with the standard.

Based on the results of the teacher survey, it was concluded that the School 2030 Biology I curriculum is not able to provide meaningful learning of biology at an optimal level. The insufficient number of lessons does not allow teachers to carry out laboratory work, include experiments, discussions, and provide individual student support, which is essential in a competence-based approach. The lack of coherence between topics and sub-topics contributes to the fragmentation of biology knowledge and affects students' understanding. In addition, the teaching of topical topics, such as immunity and evolution, lacks resources that comply with the recent developments of science. Teachers often have to adapt or create materials themselves, which increases time consumption and distracts from the individual needs of students. Unclear guidelines on the depth of topics to be covered lead to uneven understanding of the content and differences in interpretation among teachers, which can affect students' prior knowledge, as may already be the case of biology acquisition in primary school.

Teachers' insights were taken into account in the development of the methodological material. To support the biology teacher, an alternative set of methodological materials Biology I has been developed. The developed teaching materials ensure a structured, reflective, and standard-compliant teaching process, with clearly defined learning outcomes, methodological comments, and resources for each lesson. The accompanying supplementary materials, including student worksheets, laboratory work, end-of-topic tests, and other resources, contribute to a multifaceted learning process. All materials are available on the authorised skolo.lv website, providing easy and free access for teachers and students, thus contributing to the digital transformation of education, making it inclusive and open.

https://doi.org/10.33225/BalticSTE/2025.30

Implications and Recommendations

To enhance the quality of biology learning in a competence-based approach, systemic actions are needed: increasing the number of lessons, logically restructuring the curriculum, providing teaching resources, and developing clear benchmarks. These changes should be based on research-proven methods to ensure that students have the opportunity to learn life sciences as an integrated set of knowledge and skills.

As the mapping of learning outcomes did not show 100% compliance with the educational standard, not only the content but also methodological adjustments need to be made in future. The identified gaps showed that some learning outcomes of the standard are not explicitly reflected in the list of outcomes to be achieved in the programme, and this may create risks that these outcomes will not be achieved in the learning process. During the development of Biology I methodological materials, a mapping of outcomes was carried out, thus ensuring the inclusion of all learning outcomes. In the future, it would be advisable to clearly define and systematically map the learning content in order to avoid fragmentation and ensure the effectiveness of the competence-based approach. In order to harmonise educational standards - at primary, Biology I and Biology II levels - education policy makers, academic staff, and teachers should work together to identify existing coherence and suggest options for further optimisation of the educational content.

In order for the Biology I curriculum in Skola2030 to meet the objectives set out in the education standards, the number of biology lessons should be increased. According to the current Cabinet Regulation No. 416 (Ministru kabinets, 2019) schools can increase the total number of hours by 7-15% for this subject. It would be advisable to 1) review the sequence of topics and sub-topics, following the logical development of concepts (first cell structure, then DNA and heredity); 2) update teaching materials, especially in topics related to contemporary challenges (immunity, biotechnology); 3) clearly define the level of coverage of topics in the standard documents to ensure a uniform approach across schools.

The alternative set of teaching materials for Biology I has addressed the above-mentioned content inconsistencies. The digital platform skolo.lv provides the materials in an open format (PDF, DOC), allowing teachers to customise them. The current focus is on correcting and improving the materials, but in the future, they should be complemented with interactive and digital possibilities such as online tests and simulations. The development of an explanatory glossary of biology terms could be a topical issue. The inclusion of differentiated tasks and interdisciplinary materials could also enrich the learning process and stimulate students' interest in biology, despite the insufficient number of lessons.

Acknowledgements

The materials have been developed within the framework of the ESF project "Support for the Development of Individual Competences of Learners" (No 8.3.2.2.2./16/I/001). Materials were developed between 15 June 2023 and 15 December 2023.

The materials were developed by Ruta Bancāne, Airita Ešenvalde, Maruta Kusiņa, Jānis Liepiņš, Zane Lukstiņa, Erita Maurīte, Jūlija Plociņa-Kagaine, Tūrs Selga, Baiba

Skrīvele, Rūta Starka, Laisana Šakirova and Vēsma Vijupe. The team was led by Rita Birziņa, coordinated by Līga Ozoliņa-Molla, methodological support was provided by Daiga Kalniņa; skolo.lv typesetting was done by Elva Kamoliņa, funding was overseen by Vita Alle. The scientific reviewer of the materials was Professor Arvīds Barševskis from Daugavpils University. Some of the lesson materials have been used in teacher workshops and/or in schools with students.

Declaration of Interest

The authors declare no competing interest.

References

Amadio, M., Opertti, R., & Tedesco, J. C. (2014). *Curriculum in the 21st century: Challenges, tensions and open questions*. UNESCO Education Research and Foresight, Paris. [*ERF Working Papers Series, No. 9*]. https://unesdoc.unesco.org/ark:/48223/pf0000229458

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, *91*(3), 347–370. https://doi.org/10.1002/sce.20186

Biesta, G. (2009). Good education in an age of measurement: On the need to reconnect with the question of purpose in education. *Educational Assessment, Evaluation and Accountability*, *21*(1), 33–46. https://doi.org/10.1007/s11092-008-9064-9

Binder, T., Schmiemann, P., & Theyssen, H. (2019). Knowledge acquisition of biology and physics university students–the role of prior knowledge. *Education Sciences*, *9*(4), Article 281. https://doi.org/10.3390/educsci9040281

Bioloģija I metodisko materiālu komplekts skolotājiem / Set of methodological material for teachers (2023). https://skolo.lv/course/view.php?id=791639

Bioloģija I: Pamatkursa programmas paraugs vispārējai vidējai izglītībai. Programmas paraugs [Biology I: Sample basic course program for general secondary education]. (2019). Valsts izglītības satura centrs. https://mape.gov.lv/api/files/FCD1D148-D96F-4C1D-A44A-A8841BFE6148/download

Birzina, R., Cedere, D., & Petersone, L. (2019). Factors Influencing the First Year Students' Adaptation to Natural Science Studies in Higher Education. *Journal of Baltic Science Education*, *18*(3), 349–361. https://doi.org/10.33225/jbse/19.18.349

Birzina, R., Cedere, D., Dudareva, I. & Logins, J. (2023). Science students: Would I like to be a STEM teacher? In L. Daniela (Ed.) *Human, technologies and quality of education / Cilvēks, tehnoloģijas un izglītības kvalitāte*, (pp. 418–434). LU Akadēmiskais apgāds. https://doi.org/10.22364/htqe.2023.33

Bybee, R. W. (2013). *The case for STEM Education: Challenges and opportunities*. NSTA Press.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice*, *5*(1), 7–74. https://doi.org/10.1080/0969595980050102

Darling-Hammond, L. (2010). Teacher education and the American future. *Journal of Teacher Education*, *61*(1-2), 35–47. https://doi.org/10.1177/0022487109348024

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Dauer, J. T., & Long, T. M. (2015). Long-term conceptual retrieval by college biology majors following model-based instruction. *Journal of Research in Science Teaching, 52*(8), 1188–1206. https://doi.org/10.1002/tea.21258

Eija, Y. P., Eila, J., & Pongsakdi, N. (2017). Primary school student teachers' perceived and actual knowledge in biology. *CEPS Journal*, *7*(4), 125–146. https://doi.org/10.25656/01:15226

García-Pérez, N. M., & Peñaloza, G. (2025). A scoping review of interventions on middle school students' attitudes towards science. *PloS one*, *20*(1), Article e0315757. https://doi.org/10.1371/journal.pone.0315757

Harlen, W. (2015). *Working with big ideas of science education*. Global Network of Science Academies (IAP) Science Education Programme.

Harlen, W., & Qualter, A. (2004). *The teaching of science in primary schools*. David Fulton Publishers.

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.

Krajcik, J., & Shin, N. (2020). Project-based learning in STEM fields: A framework for curriculum design. *International Journal of STEM Education*, *7*(1), 1–15. https://doi.org/10.1186/s40594-020-00219-2

Krauss, A. (2024). Science of science: A multidisciplinary field studying science. *Heliyon*, *10*(17). https://doi.org/10.1016/j.heliyon.2024.e36066

Meyer, H.-D., Benavot, A., & Phillips, D. (Eds.). (2014). *PISA, power, and policy: The emergence of global educational governance*. Symposium Books.

Ministru kabinets [Cabinet of Ministers] (2019). *Ministru kabineta noteikumi Nr. 416. Noteikumi par valsts vispārējās vidējās izglītības standartu un vispārējās vidējās izglītības programmu paraugiem / Regulations Regarding the State General Secondary Education Standard and Model General Secondary Education Programmes*. Latvijas Vēstnesis 27.09.2019., Nr. 197. https://www.vestnesis.lv/op/2019/197.6

Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., & Fishbein, B. (2020). *TIMSS 2019 International Results in Mathematics and Science.* Retrieved from Boston College, TIMSS & PIRLS International Study Center website: https://timssandpirls.bc.edu/timss2019/international-results/

OECD. (2018). *The future of education and skills: Education 2030*. OECD Publishing. https://www.oecd.org/education/2030-project/

OECD. (2019). *PISA 2018 results (Volume I): What students know and can do*. OECD Publishing. https://doi.org/10.1787/5f07c754-en

Priestley, M., & Sinnema, C. (2014). Downgraded curriculum? An analysis of knowledge in new curricula in Scotland and New Zealand. *Curriculum Journal*, *25*(1), 50–75. https://doi.org/10.1080/09585176.2013.872047

Sayan, H., & Mertoglu, H. (2020). Equipment Use in Biology Teaching. *Journal of Educational Issues*, *6*(1), 357-371. https://doi.org/10.5296/jei.v6i1.17042

Skola2030 [School2030]. (2019). https://www.skola2030.lv/lv

Smith, J. P., diSessa, A. A., & Roschelle, J. (1994). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences,* 3(2), 115–163. https://doi.org/10.1207/s15327809jls0302_1

Tibell, L. A., & Rundgren, C. J. (2010). Educational challenges of molecular life science: characteristics and implications for education and research. *CBE–Life Sciences Education*, *9*(1), 25–33. https://doi.org/10.1187/cbe.08-09-0055

Tomlinson, C. A. (2014). *The Differentiated Classroom: Responding to the Needs of All Learners* (2nd Ed.). ASCD.

Verhoeff, R. P., Waarlo, A. J., & Boersma, K. T. (2008). Systems modelling and the development of coherent understanding of cell biology. *International Journal of Science Education*, *30*(4), 543–568. https://doi.org/10.1080/09500690701237780

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies*, *44*(3), 299–321. https://doi.org/10.1080/00220272.2012.668938

Wiggins, G., & McTighe, J. (2005). Understanding by design (2nd Ed.). Association for Supervision and Curriculum Development.

Received: *April 10, 2025* Accepted: *May 23, 2025*

Cite as: Birzina, R., Kalnina, D., & Kalnina, S. (2025). Development of the content of the "Biology I" set of methodological materials for a competence-based approach to secondary school biology. In. V. Lamanauskas (Ed.), *Science and technology education: Expectations and Experiences. Proceedings of the 6th International Baltic Symposium on Science and Technology Education (BalticSTE2025)* (pp. 30–46). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2025.30